# Impact of Climate Change on Agricultural Growth in Nepal[#]

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**Abstract**

*The concern of climate change has been emphasized in the field of economics too owing to the challenge of adapting to global warming for sustainable development and growth. This challenge becomes dominant in the developing economies like Nepal as these countries face the combination of equator vulnerable climate change pattern, agro-based economy, scarcity of resources, and lack of influence to put forth the global agenda of climate change to international forum. In this paper, we conducted a quantitative modeling of climate change and its impact to the agricultural value addition in Nepal taking into consideration annual series of agricultural gross domestic product (AGDP), rainfall, temperature, seeds and fertilizer distribution data for the period of 36 years ranging from 1975 to 2010. The statistical inferences show the significant positive impact of rainfall to the AGDP. Nevertheless, improved seeds and chemical fertilizers are found to be insignificant. The impact of rising temperature to AGDP is cautious as we find a large negative coefficient of cyclical component of temperature, but statistically insignificant. This insignificance may be due to the nature of very little temperature variability over the study period as compared to the variability in AGDP. The country should assess the impact of climate change in national, regional, and district level to collect the spatial information and underpin the adaptive policies to the required areas.*

**Key Words:** Agricultural GDP, Climate Change, Growth
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# I. INTRODUCTION

Global warming and climate change are the great concern of today since they affect not only the living beings but also the whole ecosystem of this world. However, its impact on agriculture can be understood directly as agro sector is more dependent on natural nurture. This concern is equally applicable to Nepal too as early symptoms of climate cruelty[1] and alarmingly increased temperature have been observed almost in double pace within shorter time horizon[2] compared to global temperature rise. Furthermore, Nepal is a rice importer in the last few years whereas it was exporter in the past. Likewise, amidst the millennium development goals and agriculture perspective plan (APP) 1996–2015, Nepal always faces food grains deficit in more than 27 districts in the hill and high hill regions.

Productivity and quality of food production is also in question in Nepal as both of them are deteriorating. Excess and improper use of chemical fertilizer and pesticides has further prompted for health hazards and soil contamination in particular and increasing pollution in general. Recently, there was news coverage that the Middle Marshyangdi Hydro Project, which was initially producing around 70 megawatt electricity, now generating only around 50 megawatts because of decreased water level and weak flow especially in the winter and summer. Obtaining such results are believed to be the consequences of rising global warming and climate change.

As we observe the growth of plant as well as the yield is primarily determined by the climatic settings of the particular topography, the major constraints of the plant growth and yields are rainfall, sun light, and temperature (Gurusamy, 2008). Since Nepalese agriculture sector contributes more than one third to the Gross Domestic Product (GDP) and employs more than two third of the total labor force, the impact of climate change and its magnitude can have direct and substantial to the economy. Although there has been a serious concern towards the mitigation and adaptation of climate change, the scientific study to capture the impact of climate variability and the vulnerability to the agricultural sector especially to the production is yet to be identified in our context.

In this milieu, this paper tries to explore the time trend of agriculture gross domestic product (AGDP), use of agriculture inputs (chemical fertilizer, improved seeds etc.), precipitation, and temperature and their role in agricultural production of Nepal. Based on these variables, this paper equally delineates with the quantitative modeling to find out the likely impacts of climate change on AGDP. Along this course, section II begins with the empirical literature survey; section III develops the data, model and methodology; section IV deals on graphical presentation about the trends of AGDP, using agricultural inputs, precipitation and average temperature; section V explains the test results and

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[1] Samjung and Dhea Villages of Mustang District have been on bank of Kali Gandaki River because of climate impacts in Nepal (for greater detail, refer to Acharya, 2011.

[2] For greater detail, refer to Acharya, 2012.

findings of the study. And, finally, section VI summarizes and concludes with some reasonable policy prescriptions.

There are some limitations of the paper. Climate change is considered as a global impact, not a local one. Hence, the temperature and rainfall, indicated as climate change variables, may be studied in the cross-country framework abut to Nepal. Moreover, the availability of time series is limited to thirty six years due to the unavailability of temperature and rainfall data of older periods. Seeds and fertilizers distribution data accounts only of those government statistics, whereas there may be a maximum share of private entities which is not captured in this analysis. The quarterly frequency of the data could have explained more than that of annual frequency which is ruled out in the analysis due to the unavailability of data frequency less than a year, especially the AGDP.

## II. LITERATURE SURVEY

There are less than expected empirical works on the impact of global warming and climate change on AGDP especially in Nepalese context. Independent and individual research seems beyond that catch as the climate and precipitation time series are unaffordable to ordinary people in Nepal. This study has been conducted with a general intuition and particularly based on the limited literature review in the Nepalese context.

Acharya (2012) revealed that the higher side temperature rise seems terrible as it is nearly 2.0°C on an average in the western Nepal which is almost three times of the lower average temperature. Such temperature rise in Nepal, if compared to global trend, is significantly higher. Furthermore, Hills and high hills are more vulnerable to climate change.

Malla (2008) has revealed that with an average of 0.06°C a year, a rise in temperature from 1975 to 2006 by 1.8°C has been recorded in Nepal. Problem of frequent drought, severe floods, landslides and mixed type of effects in agricultural crops have been experienced in the country because of climate change. Study done on $CO_2$ enrichment technology at Khumaltar revealed that the yield of rice and wheat increased by 26.6 percent and 18.4 percent due to double $CO_2$, 17.1percent and 8.6 percent due to increase in temperature respectively. A crop simulation model (DSSAT) to study the effects of $CO_2$, temperature and rain in National Agriculture Research Center (NARC) record showed positive effect in yield of rice and wheat in all regions, but negative effect in maize especially in Terai.

Panta (2009) reviews the literature on both the aspects and test empirically that what affects emissions of carbon dioxide to the atmosphere. Data on carbon emissions, energy consumption and agriculture related national level variables are obtained for 120 countries from the World Bank's Green Data Book. Multiple linear regression analysis revealed that agricultural land, irrigation, forest area, biomass energy, and energy use efficiency negatively affect the Carbon dioxide emission. But, fertilizer use and per capita energy use affect it positively. The analysis confirms that the people in rich countries are more responsible for carbon emission than the people in poor countries. It recommends for cross subsidization for low external input agriculture, particularly for organic farming in poor countries.

Cline (2007) infers that the agricultural damages tend to be greater toward the equator, and hence concentrated in developing countries. Yields and agricultural production potential would fall about 15 to 30 percent in Africa and Latin America and 30 to 40 percent in India. For the United States, the effects would be severe for the south but milder and conceivably even positive for a while for the north. Productivity losses would range between 20 and 30 percent in the southeast, and from 25 to 35 percent in the southwest plains and Mexico.

Guiteras, R. (2007) studied the effect of random year-to-year variation in weather on agricultural output using a 40 year district level panel data set covering over 200 Indian districts. The study results suggest that climate change is likely to impose significant costs on the Indian economy unless farmers can quickly recognize and adapt to increasing temperatures. Such rapid adaptation may be less plausible in a developing country, where access to information and capital is limited.

Dell, Jones and Olken (2011) revealed three primary results that (a) higher temperatures substantially reduce economic growth in poor countries (b) higher temperatures appear to reduce growth rates, not just the level of output, and (c) higher temperatures have wide-ranging effects, reducing agricultural output, industrial output, and political stability.

Zhai, Lin., and Enerelt (2009) have studied the potential long term impacts of global climate change on agricultural production and trade in the People's Republic of China (PRC). Using an economy-wide, global computable general equilibrium model, the simulated scenarios of global agricultural productivity change induced by climate change up to 2080 has revealed results that with the anticipated decline in agriculture share of gross domestic product, the impact of climate change on the PRC's macro economy will be moderate. The food processing subsectors are predicted to bear the brunt of losses from the agricultural productivity changes caused by climate change. Production of some crop sectors (such as wheat), in contrast, is likely to expand due to increased demand from other regions of the world.

Fischer et.al. (2002) asses the sensitivity of agro-ecosystems to climate change by applying the agro-ecological zones (AEZ) methodology developed by the Food and Agriculture Organization of the United Nations (FAO) and the International Institute for Applied Systems Analysis (IIASA). Using Geographic Information System (GIS) under the Basic Linked System (BLS) modeling framework, the methodology identifies crop-specific environmental impacts with varieties of inputs and management conditions. The study finds that climate change has significant impact on crop agriculture, variability of rain-fed cereal production, changes in agricultural land (both increase and decrease), crop-production pattern and the potential to cereal production. The impact (positive as well as negative) and its severity vary region to region. The impact of climate change on

GDP for the aggregate global level is found to be quite small (between -1.5 percent to +2.6 percent) with developing regions seem to have negative impact to it. For the Asian region, around 4 percent negative impact on GDP was revealed. Nevertheless, developed countries seem likely to benefit from the climate change. Developing countries consistently experience reductions in cereal production in all climate scenarios and production may move to developed regions especially to North America and the former Soviet Union.

Bezabih, Chambwera, & Stage (2010) concluded that despite the projected reduction in agricultural productivity, the negative impacts can potentially be quite limited. This is because the time scales involved and the low starting point of the economy leaves ample time for factor substitutability (i.e. replacing reduced land productivity with increased use of capital and labor) and increased overall productivity. This indicates the policies that give farmers opportunity to invest in autonomous climate adaptation, as well as policies that improve the overall performance of the economy, can be as important for reducing the impacts of climate change in the economy as direct government policies for climate adaptation.

The aforementioned empirical literatures confirm that climate change has significant impact on agriculture production. The impact, however, can be both positive as well as negative. The developed countries, countries towards the North Pole, including North America, former Soviet Union are seem to be benefited from the climate change due to the increased cereal production, ample resources for factor substitutability and some others. Nonetheless, the negative impact tends to be greater toward the equator, and hence mostly concentrated in developing countries. Developing countries are more vulnerable to climate change especially to the agriculture production lacking adequate resources for the adaptation and substituting the production factors, agriculture based economy, food insecurity and poverty. In this context, the country specific quantitative relationship of climate change (especially that of rainfall and temperature) to the agricultural GDP still deficit in Nepalese context that this paper wants to fill the gap.

## III. DATA AND METHODOLOGY

The model uses the annual data of agricultural gross domestic product (AGDP), average rainfall, temperature, seeds and fertilizer distribution in Nepal. The GDP data is obtained from central bureau of statistics (CBS), rainfall and temperature data are obtained from department of hydrology and meteorology (DHM) that covers the collection of major 15 (Dadeldhura, Dhangadi, Jumla, Surkhet, Nepalgunj, Jomsom, Bhairahawa, Pokhara, Simara, Parwanipur, Kathmandu, Janakpur, Okhaldhunga, Biratnagar, and Taplejung) center's data across Nepal, and seeds and fertilizer distribution data have been extracted from economic survey published by Ministry of Finance (MoF). The span of data set is covered from 1975 to the 2010 with the reason of availability of unbroken series of temperature and rainfall data.

The production of an economy is largely affected by the major factors of production, namely, land, labor, capital and technology. Besides these, other factors play a dominant role for the agriculture sector, including rainfall, availability of seeds, chemical fertilizers and irrigation facility. The impact of rainfall and temperature to the output to this sector may be significant especially to those developing and least developed economies owing to the unavailability of irrigation, problem in improved seeds and getting fertilizers. As mentioned in section two of the paper, the rise in global temperature may change the cropping pattern and most importantly, the output.

In this context, the agricultural value addition (AGDP) can be defined as:

AGDP = f(temp, rain, seeds, irrigation, fertilizer, land, labor, capital, technology, ε)

The regressors land, labor, capital and technology are assumed to be stock variables over the study period presuming that those variables will remain constant. The variation into the AGDP, hence, can be explained by the rests. The re-defined relationship can be modeled as follows:

$$AGDP_t = \alpha + \beta_1 rain_t + \beta_2 temp_t + \beta_3 seeds_t + \beta_4 chem_t + \beta_5 irrigation_t + \varepsilon_t \;\ldots\ldots\; (1)$$

The subscript *t* denotes year, $AGDP_t$ denotes total real value addition of the agricultural sector in the given year, $rain_t$ is the annual average rainfall in milliliters, $temp_t$ represents the annual average temperature calculated from the average of minimum and maximum temperature of fifteen centers across the country, $seeds_t$ and $chem_t$ are the annual sales of improved seeds and chemical fertilizers distributed by Agricultural Input Corporation, given in the metric tons; and $irrigation_t$ is the total fully irrigated land in the country, given in the hectares.

The main hypothesis is that rainfall and temperature are the two most significant variables for the agricultural production. We hypothesize a positive impact of rainfall and a negative impact of temperature in the AGDP. Hence, the sign of $\beta_1$ is expected to be positive and the sign of $\beta_2$ is to be negative. Additional hypothesis is that seeds, fertilizer and irrigation extension have significant positive impact to the AGDP and the sign of coefficients $\beta_3$, $\beta_4$ and $\beta_5$ are also likely to be positive.

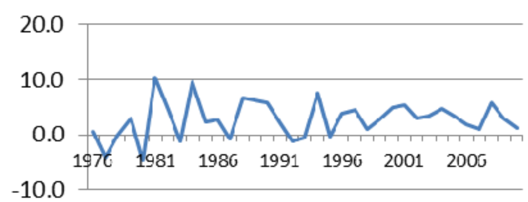
Before estimating the equation (1), the stationarity of the series is tested in each of the variables graphically as well as statistically. The Augmented Dickey Fuller (ADF) test for unit root is applied for the statistical identification of stationarity. The reason of using this method instead of others for determining the stationarity is that it gives the number of optimal lags to be included. The lag-length criterion is determined automatically by applying Schwarz Info Criterion (SIC). The variables found stationary is included at level whilst which are stationary only at first difference are included accordingly. Nevertheless, trend-stationary variables are smoothened with Hodrick Prescott (HP) Filter before including it in the regression equation. HP Filter minimizes the variance of the old series around the new one, subject to a penalty constant that constrains the second difference of the smoothed series (please refer Annex 1 for the HP Filter equation).

## IV. TRENDS OF MAJOR STUDY VARIABLES

In order to get some initial idea and nature of the series used in the study over the time to postulate the certain level of inference, time plots of the concerned variables are exhibited in several graphs correspondingly.

Time plot containing annual growth of agricultural gross domestic product (AGDP) is displayed in the Figure 1 for the past 36 years. The plot shows volatile pattern indicating instability of growth over the years.

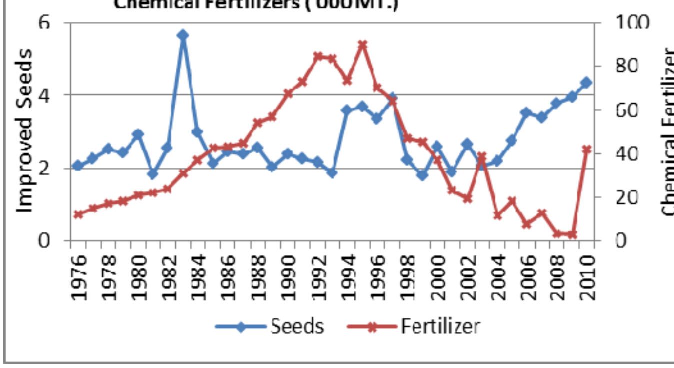
**Figure 1: Annual Growth of Agricultural GDP**




*Data Source: Central Bureau of Statistics*

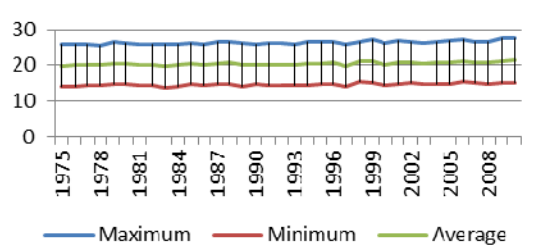
Time plots of the agricultural inputs (chemical fertilizers and improved seeds) show a random movement over the period. Although improved seeds distribution seems a gradual increment in the recent years, distribution of chemical fertilizer started to drop from 1993. Before that, we observe a stable rising trend of chemical fertilizer distribution up to 1992 (Figures 2).

**Figure 2: Annual Distribution of Improved Seeds and Chemical Fertilizers ('000MT.)**




*Source: Economic Survey Various Issues, Ministry of Finance*

**Figure 3: Temperature Variation in Nepal ($^0$C)**

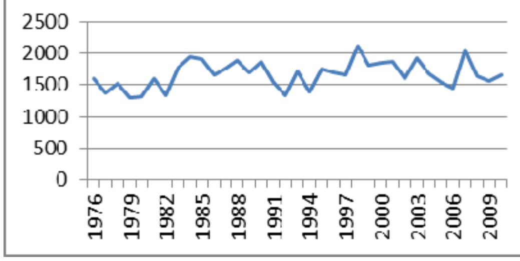



*Data Source: Department of Hydrology and*

Time plot of temperature displayed in Figure 3 shows that temperature of different categories i.e. annual maximum average, annual overall average and annual minimum average are in increasing trend.

Time plots of precipitation displayed in Figure 4 shows that the variation of rainfall is in mixed trend in general and most of the time to decline during the study period.

**Figure 4: Annual Average Variation of Rainfall in Nepal (MM)**




*Data Source: Department of Hydrology and*

The graphical plots of the model variables taken under study show mixed movements as the AGDP is much volatile, agro-inputs are increasing, annual average temperatures are rising and rainfall is relatively decreasing. Such mixed movements might have either offsetting impacts or negative impacts on the agriculture production in the country. In order to measure such linkages amongst variables, one must run several empirical tests to find out the exact and proportional effects of the explanatory variables on dependent variable. For this, some established tests and models are run in the text follows.

## V. RESULT ANALYSIS

The graphical plot of the observed variables show that $AGDP_t$ and $temp_t$ are non-stationary processes whereas $rain_t$, $seeds_t$, and $fertilizer_t$ do not clearly indicate whether they are stationary. The statistical approach is applied to test the stationarity of each variable. The Augmented Dicky-Fuller (ADF) test statistics for the unit roots is presented in Table 1.

**Table 1: Augmented Dickey-Fuller (ADF) Test for Unit Roots**

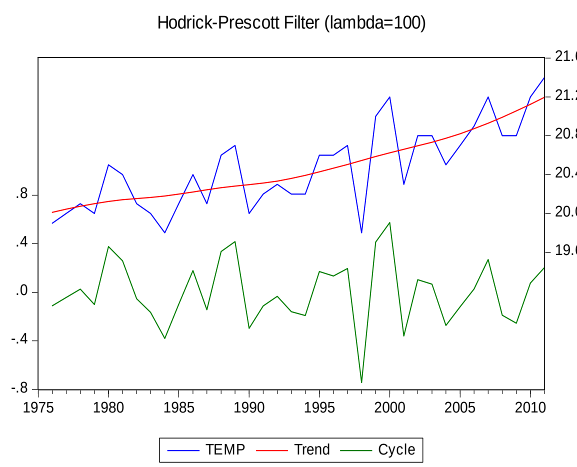
| Variables | Intercept | | | | Intercept and Trend | | | |
|---|---|---|---|---|---|---|---|---|
| | Level | | First Difference | | Level | | First Difference | |
| | t-stat | p-value | t-stat | p-value | t-stat | p-value | t-stat | p-value |
| *Chem* | -3.7173 | 0.0099 | -5.7014 | 0.0000 | -3.8913 | 0.0273 | -5.6861 | 0.0003 |
| *AGDP* | 2.1976 | 0.9999 | -5.7199 | 0.0000 | -1.8124 | 0.6778 | -6.7720 | 0.0000 |
| *Rain* | -4.5696 | 0.0008 | -6.9551 | 0.0000 | -4.8749 | 0.0020 | -6.8806 | 0.0000 |
| *Seeds* | -3.6019 | 0.0110 | -7.3036 | 0.0000 | -3.7506 | 0.0322 | -7.2105 | 0.0000 |
| *Temp* | -0.7244 | 0.8268 | -8.5424 | 0.0000 | -5.3615 | 0.0006 | -8.4485 | 0.0000 |
| *Lchem* | -3.2921 | 0.0258 | -1.1429 | 0.6821 | -2.9157 | 0.1740 | -1.7435 | 0.7011 |
| *LAGDP* | 0.7613 | 0.9919 | -6.6165 | 0.0000 | -4.1779 | 0.0115 | -6.7608 | 0.0000 |
| *Lrain* | -4.4930 | 0.0010 | -6.89962 | 0.0000 | -4.8245 | 0.0023 | -6.8189 | 0.0000 |
| *Lseeds* | -3.5330 | 0.0130 | -7.2290 | 0.0000 | -3.7028 | 0.0358 | -7.1342 | 0.0000 |
| *Ltemp* | -0.7561 | 0.8183 | -8.5364 | 0.0000 | -5.3879 | 0.0005 | -8.4382 | 0.0000 |

The ADF test for unit root shows that variables $chem_t$, $rain_t$ and $seeds_t$ are stationary processes at both level and first difference. The results are also consistent after taking the natural log of the respective variables. Moreover, with the intercept in the equation, variables $AGDP_t$ and $temp_t$ have unit root, whilst stationary at the first difference. Nevertheless, the temperature variable ($temp_t$) is stationary at level if both intercept and trend are included in the test equation. This result shows a trend-stationary nature of $temp_t$, concluding that, including $temp_t$ with a first differentiation may show a spurious relationship among the variables. The temperature variable requires smoothing by applying some available smoothing techniques for the trend-stationary variables.

Enders (2010) illustrates that if a variable is trend-stationary and the cointegration relations among the variables of interest (that we include in the model) is I(2), then smoothing the series by Hodrick-Prescott (HP) filter gives the best result[3] and does not introduce the spurious relationships. Another advantage of applying HP filter is, as against of other decomposition methods, this approach uses the same procedures to filter the trend and cycle if we have set of variables.

Hence, the trend from the variable $temp_t$ is extracted and decomposed into two different series: $trend_t$ and $cycle_t$. Now, we use the smothered series, $cycle_t$ to the model since cycle has the information to analyze the effects. The new series after the extraction of trend is named as $cyclesm_t$ for the better identification of it. The graphical output of smothered series is presented in Figure 5.

Figure 5: HP Filter for Temperature Data




Based on the unit root test and other aforementioned methodological analyses, the model can be fit as:

$$\Delta AGDP_t = \alpha + \beta_1 rain_t + \beta_2 cyclesm_t + \beta_3 seeds_t + \beta_4 chem_t + \varepsilon_t \qquad \ldots\ldots (2)$$

Where, $\Delta AGDP_t$ is the first difference of the agricultural GDP and $cyclesm_t$ is the decomposed and smothered series of the variable $temp_t$ by applying HP Filter technique

[3] The trace statistics of Johansen Co-integration test with the variables of interest of analysis (GDP, RAIN and TEMP), unrestricted and no constant terms, shows that there is an integration of order two, i.e. I(2) relationship. Maximum eigenvalues also confirms the result of two co-integration equations at 0.05 level of significance. See Annex 3 for the detailed statistical output.

of smothering trend-stationary regressor. The variable *irrigation*$_t$ has been removed from the model of analysis because of the unavailability of total fully irrigated area of land in the country each year; although extension of the facility to additional hectare is available.

Fitting the model with the statistical output,

$$\Delta AGDP_t = -13381.72 + 9.66 rain_t - 541.89\, cyclesm_t + 0.53 seeds_t - 0.015 chem_t$$
$$(-1.748)^{*} \quad (2.897)^{**} \quad (-0.265) \quad (0.681) \quad (-0.708)$$

$R^2$= 0.309, Adj. $R^2$= 0.217, F-test = 3.352, P-value=1.83, DW Test- 1.83
* = significant at 10% level, ** = significant at 1% level

The values in the parentheses indicate the t-statistics. The t-statistics show that *rain*$_t$ is significant at 1 percent level of significance. The other regressor; *cyclesm*$_t$, *seeds*$_t$ and *chem*$_t$ are insignificant. In the statistical output, the sign of the variables are as expected in the methodology except for the variable *chem*$_t$. The ***rain*$_t$ *has a positive impact on agricultural GDP in Nepal,*** *showing that* **one additional milliliter of rainfall adds Rs. 9.6 million values into the agricultural output**. In another words, one unit rainfall causes agricultural output to increase by 9.6.

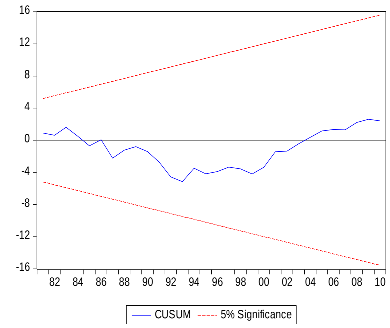
Although the *cyclesm*$_t$ is not significant, the impact of the climate change, i.e., rise in temperature seems to have negative impact on the agricultural value addition; the sign of $\beta_2$ is negative. It shows that ***one degree rise in temperature would have a huge loss in agricultural production, causing to decrease the value addition by Rs. 542 million***. The rationality of insignificance in the statistical relation can be argued as a very little change of *cyclesm*$_t$ over time in comparison to the change in *AGDP*$_t$ that couldn't statistically be captured within the short horizon of time. It is expected that longer series of production and temperature may result the significance of *cyclesm*$_t$. The major reason in the insignificant relation to the agricultural production of other two variables *seeds*$_t$ and *chem*$_t$ can be regarded as underestimated figure of both variables because we do not incorporate seeds and chemical fertilizer distribution data of private sectors.

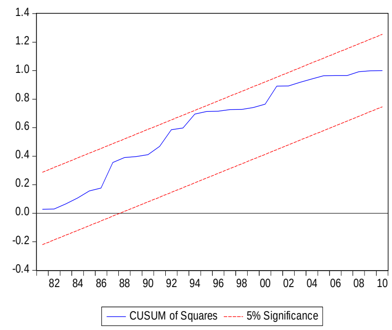
## 5.1 Model Diagnostics Tests

The F-statistics (3.352) shows the overall significance of the model at 5% level (p-value = 0.022). The value of Durbin-Watson statistics is 1.83 which shows satisfactory results. Adjusted $R^2$ is 0.217 indicating model currently explains 22% of the relationship that can be improved further. Correlogram of Q-Stat shows both Autocorrelation and Partial Correlation in the residuals are within the accepted range, showing all the spikes inside the given range bar (Annex 4). The Breusch-Godfrey Serial Correlation Lagrange Multiplier (LM) test for the autocorrelation in the residuals shows there is no serial correlation in the residuals. We fail to reject the null hypothesis of no serial correlation at lag order two, i.e., F-statistics is 0.3489 with 0.7084 p-values (Annex 5).

The CUSUM and CUSUM Squares test for stability of the model also shows that the recursive estimates calculated from the regression equation are within the range at 5% level of significance (Figure 6).

Figure 6: CUSUM test for stability




## VI. CONCLUSION

Presently, there is a prime concern of the rising global warming, increased food insecurities and other consequences of climate change throughout the world. The impact of climate change is much direct to the agriculture sector, especially through the change in cropping pattern due to rise in temperature and rainfall pattern in the country, use of pesticides in crops and some others. Notwithstanding agro-based economy, Nepal is a net importer of many agro-products and the trend of being so is rising every year. The growth in agricultural sector determines the overall growth of the economy, as the sector contributes more than one third in the total value addition and employs more than two-third of the labor force. In the given context, we have tried to capture the impact of climate change variables into the agriculture output in Nepal considering as Agricultural GDP dependent variable and annual average temperature, rainfall, use of chemical fertilizer and seeds as independent.

The statistical results show a significant positive relationship of rainfall to the AGDP in Nepal which can be taken positively at least for the transition. Since the contribution of the AGDP is large to the GDP, it can be inferred that Nepal's growth primarily depends upon the average rainfall, as country witnesses more rainfall, accordingly higher growth rate can be expected. Furthermore, rise in temperature may largely affect the AGDP, which could not be inferred statistically, at least in this empirical measurement, as the relationship is insignificant. Nevertheless, seeds and chemical fertilizer could not impact on AGDP, as the statistical relation is insignificant. In the developing countries like ours, due to the lack of sufficient and reliable irrigation facilities, agricultural growth largely depends upon the rainfall. Since rainfall is also greatly affected by the change in temperature, now we can conclude that climate change has both direct and indirect impact to the gross domestic product (GDP).

Thus, the stability of economic growth is questionable in Nepal due to the monsoon based growth. If the country witnesses drought, it has dual impact on the economy; that is, sharp reduction of AGDP, and low energy output owing to the run-off-the river hydropower resulting in a significant drop of economic growth. For the higher value addition to the agriculture sector, emphasis should be given to the irrigation extension, rather than that of improved seeds and distribution of subsidized chemical fertilizers.

Furthermore, it is important to assess, compare and evaluate the impact of climate change in Nepal in national, regional, and even district level to identify the variation of the impacts on food and agricultural production systems. As the impact may be positive, negative and even indifferent in different geographies of the country, the spatial information can be an important input to bring forward the adaptive policies to the required areas within the nation so as to mitigate the consequences. Since climate change is a global issue, developing countries like Nepal should emphasize on adaption measures rather than mitigation. The voice to international forums is to be raised for the costs of climate change that the country is bearing, for instance, use of pesticides for plants and diseases, changes in rainfall pattern along with natural disasters, impact on biodiversity and many others.

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## ANNEXES

### 1. Hodrick-Prescott (HP) Filter Equation

It minimizes the variance of the old series around the new one, subject to a penalty constant λ , that constrains the second difference of the smoothed series i.e. *smcycle*$_t$.

That is, the HP filter chooses *smcycle*$_t$ to minimize:

$$\sum_{t=1}^{T}(ltemp_t - smltemp_t)^2 + \lambda \sum_{t=2}^{T-1}\left((smltemp_{t+1} - smltemp_t) - (smltemp_t - smltemp_{t-1})\right)^2$$

The penalty parameter λ controls the smoothness of the series σ. The larger the λ, the smoother the σ. As λ =∞, *smcycle*$_t$ approaches a linear trend.

### 2. E-Views output of the Equation no. (2)

Dependent Variable: D(GDP)
White heteroskedasticity-consistent standard errors & covariance

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | -13381.72 | 7652.393 | -1.748698 | 0.0906 |
| RAIN | 9.657000 | 3.333226 | 2.897193 | 0.0070 |
| CYCLESM | -541.8866 | 2044.126 | -0.265095 | 0.7927 |
| SEEDS | 0.530556 | 0.778860 | 0.681195 | 0.5010 |
| CHEM | -0.014993 | 0.021165 | -0.708365 | 0.4842 |

| | | | |
|---|---|---|---|
| R-squared | 0.308883 | Mean dependent var | 3657.057 |
| Adjusted R-squared | 0.216734 | S.D. dependent var | 3718.953 |
| S.E. of regression | 3291.360 | Akaike info criterion | 19.16755 |
| Sum squared resid | 3.25E+08 | Schwarz criterion | 19.38975 |
| Log likelihood | -330.4322 | Hannan-Quinn criter. | 19.24425 |
| F-statistic | 3.351994 | Durbin-Watson stat | 1.833216 |
| Prob.(F-statistic) | 0.022082 | | |

## 3. Unrestricted Cointegration Rank Test of GDP, RAIN and TEMP

Unrestricted Cointegration Rank Test (Trace)

| Hypothesized No. of CE(s) | Eigenvalue | Trace Statistic | 0.05 Critical Value | Prob.** |
|---|---|---|---|---|
| None * | 0.619069 | 68.51302 | 35.19275 | 0.0000 |
| At most 1 * | 0.549291 | 35.69838 | 20.26184 | 0.0002 |
| At most 2 | 0.223546 | 8.602627 | 9.164546 | 0.0638 |

Trace test indicates 2 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

| Hypothesized No. of CE(s) | Eigenvalue | Max-Eigen Statistic | 0.05 Critical Value | Prob.** |
|---|---|---|---|---|
| None * | 0.619069 | 32.81464 | 22.29962 | 0.0012 |
| At most 1 * | 0.549291 | 27.09575 | 15.89210 | 0.0006 |
| At most 2 | 0.223546 | 8.602627 | 9.164546 | 0.0638 |

Max-eigenvalue test indicates 2 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

## 4. Correlogram (Q-Stat) of Residuals

| Autocorrelation | Partial Correlation | | AC | PAC | Q-Stat | Prob |
|---|---|---|---|---|---|---|
| | | 1 | 0.048 | 0.048 | 0.0882 | 0.766 |
| | | 2 | -0.136 | -0.139 | 0.8134 | 0.666 |
| | | 3 | 0.081 | 0.097 | 1.0764 | 0.783 |
| | | 4 | -0.128 | -0.163 | 1.7589 | 0.780 |
| | | 5 | -0.191 | -0.153 | 3.3368 | 0.648 |
| | | 6 | 0.099 | 0.078 | 3.7774 | 0.707 |
| | | 7 | 0.172 | 0.146 | 5.1472 | 0.642 |
| | | 8 | 0.043 | 0.063 | 5.2341 | 0.732 |
| | | 9 | 0.081 | 0.061 | 5.5589 | 0.783 |
| | | 10 | -0.012 | -0.043 | 5.5661 | 0.850 |
| | | 11 | -0.032 | 0.054 | 5.6216 | 0.897 |
| | | 12 | 0.045 | 0.094 | 5.7356 | 0.929 |
| | | 13 | 0.098 | 0.122 | 6.3054 | 0.934 |
| | | 14 | -0.113 | -0.144 | 7.0894 | 0.931 |
| | | 15 | 0.117 | 0.125 | 7.9750 | 0.925 |
| | | 16 | 0.022 | -0.049 | 8.0069 | 0.949 |

## 5. Lagrange Multiplier(LM) test for Autocorrelation of Residuals

Breusch-Godfrey Serial Correlation LM Test:

| | | | |
|---|---|---|---|
| F-statistic | 0.348954 | Prob. F(2,28) | 0.7084 |
| Obs*R-squared | 0.851170 | Prob. Chi-Square(2) | 0.6534 |